



Electro-biochemical Rector: increased water treatment performance and cost-effectiveness

Jack Adams, Ph.D.

Ola Opara

Mike Peoples



NATIONAL 2010 CLEAN TECH OPEN:
WINNER ROCKY MOUNTAIN REGION

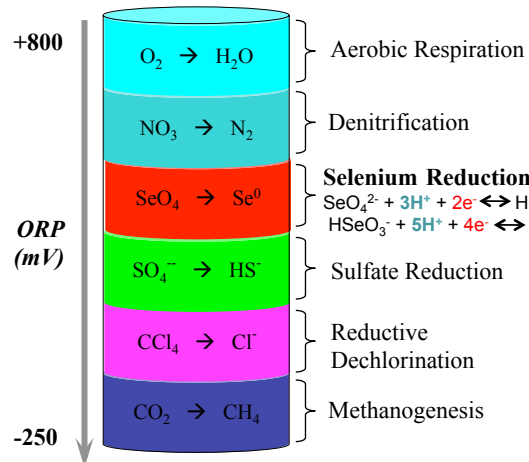


INOTEC -DOGM _ST. GEORGE, UT -3/2012

Biological Treatment Principles

Oxidation /Reduction - Redox

Groundwater
+
Substrate

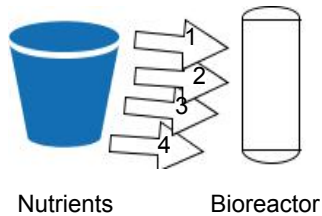


- Both **hydrogen** and **electrons** are required for effective selenium reduction and removal (Both electrons and electron acceptors)

Background

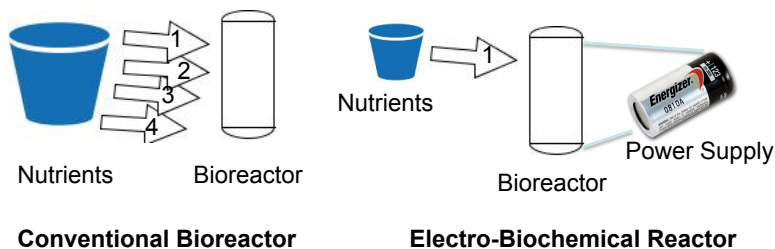
Conventional Biological Treatment

- In conventional systems, a large excess of nutrients /chemicals are required to:
 1. Provide C:N:P components for microbial growth
 2. Provide the electrons and electron acceptor environments needed for contaminant removal
 3. Adjust reactor chemistry
 4. Compensate for system inefficient and fluctuating electron availability

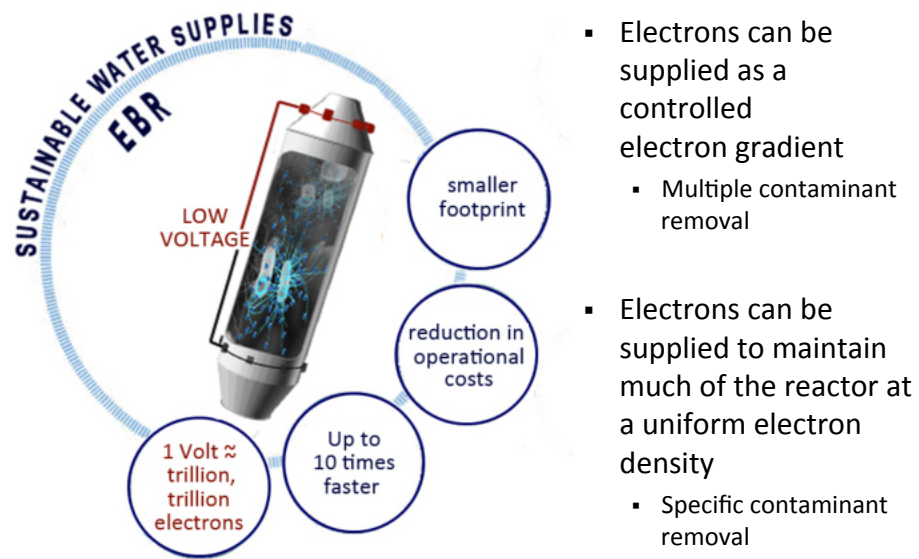


Electro-biochemical Remediation

- Amount of electrons supplied by nutrients varies
 - Glucose [$C_6H_{12}O_6$] = 72 grams carbon/mol = **24 e⁻/mol**
 - Glycerol [$C_3H_8O_3$] = 36 grams carbon/mol = **14 e⁻/mol**
- Amount of electrons supplied by 1 Volt:
 - **~1 trillion trillion** electrons



Electro-biochemical Remediation

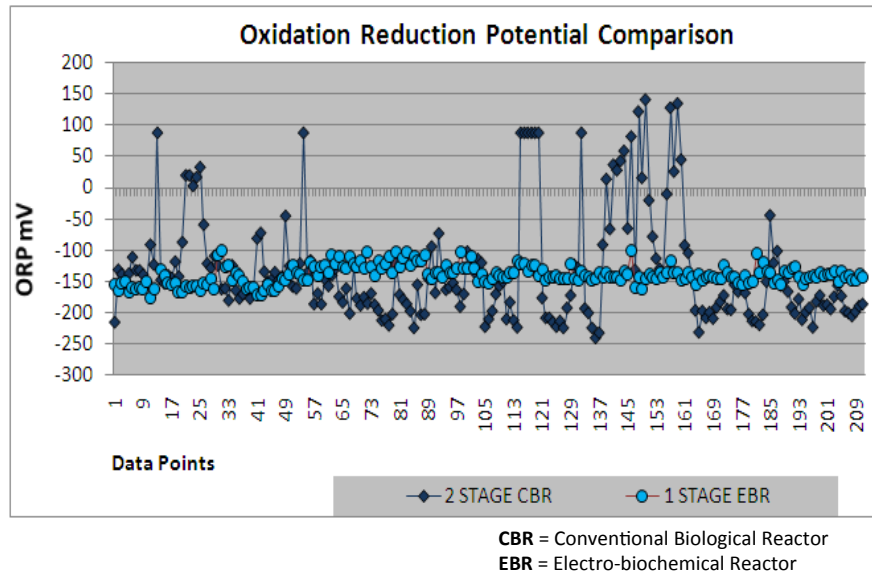


Electro-biochemical – Laboratory Results

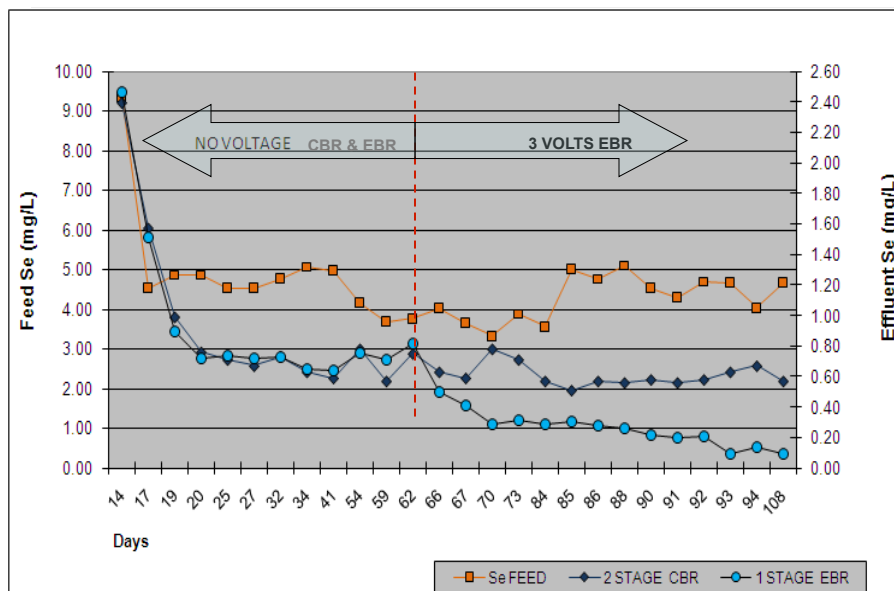


- Ten successful bench-scale tests on various wastewaters from:
 - hard rock mines and coal mines
- Containing:
 - selenium and nitrate
 - arsenic and nitrate
 - mercury

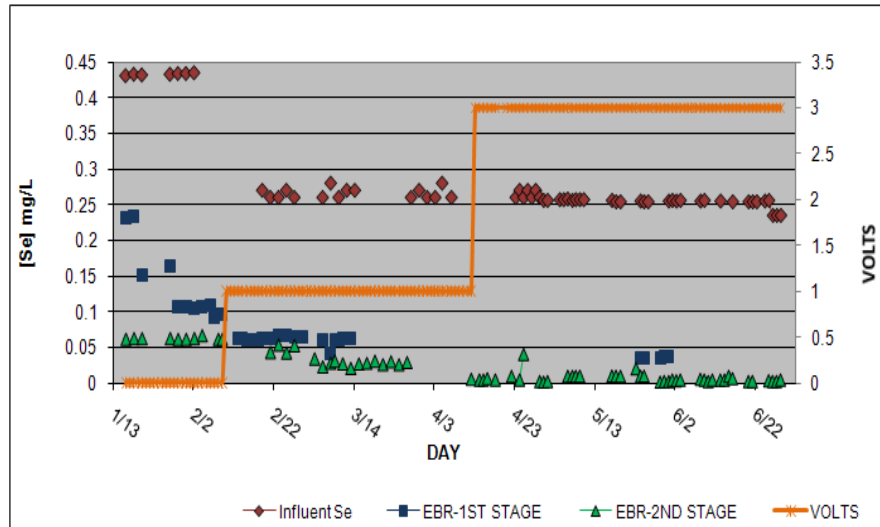
Redox Stability – Laboratory Results



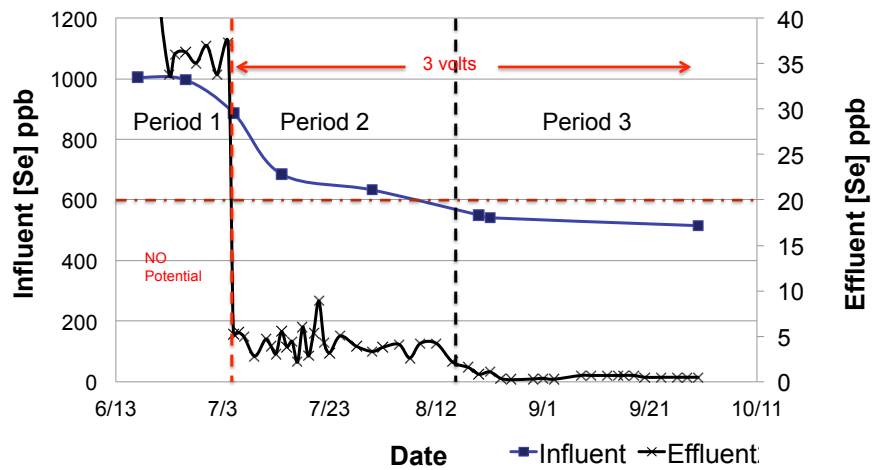
Process Water – EBR Selenium Results



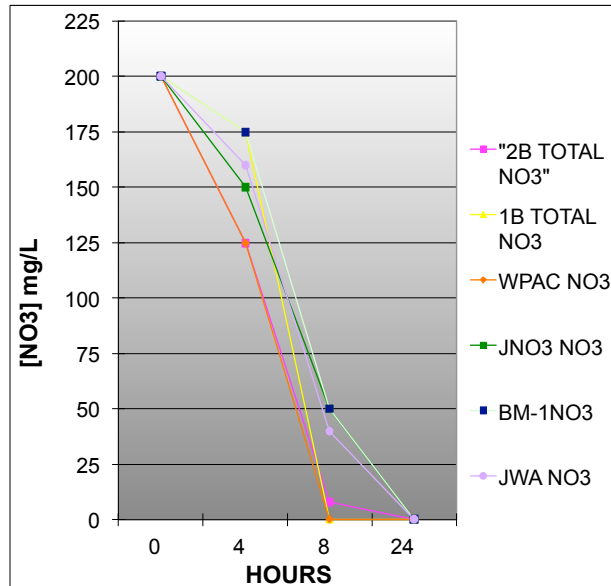
Coal Mine Drainage – EBR Selenium Results



Coal Mine Drainage – EBR Selenium Results

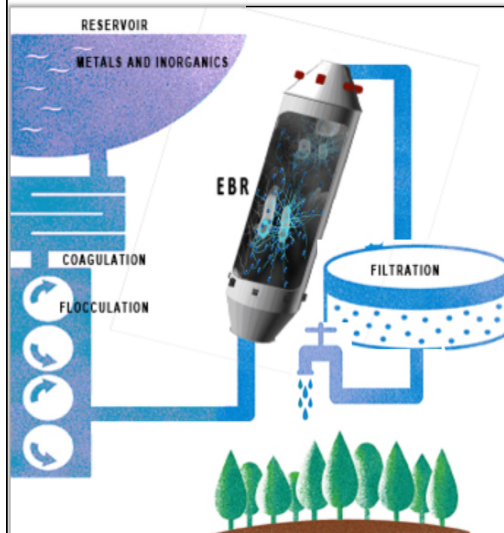


EBR – Laboratory Denitrification



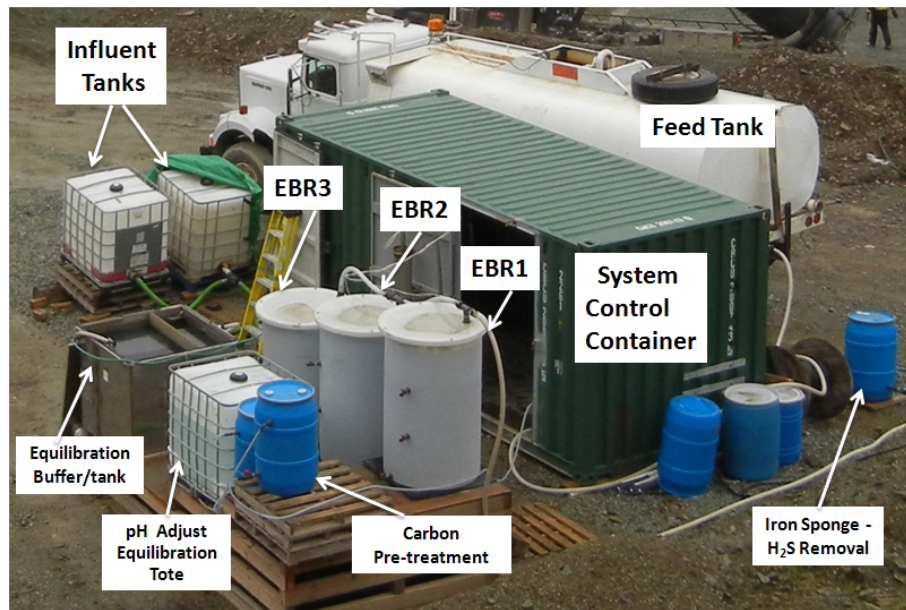
- Denitrification rates reached >95 mg nitrate-N per hour

Electro-biochemical Reactor (EBR) - Field-scale



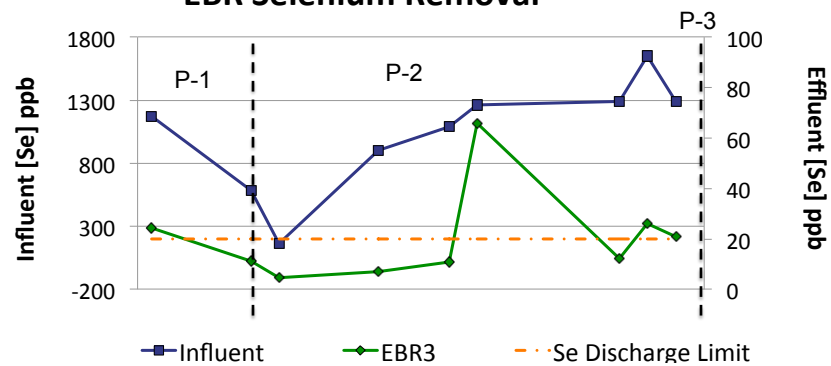
- Like all other metal removal technologies, the Electro-biochemical Reactor is part of a complete treatment system that has multiple components
- The treatment system components required for each site are determined and sized through:
 - Water chemistry analysis
 - Discharge criteria
 - Bench-scale tests
 - Pilot-scale tests

Pilot-scale Validation and Evaluation



Pilot-scale Validation and Evaluation

EBR Selenium Removal



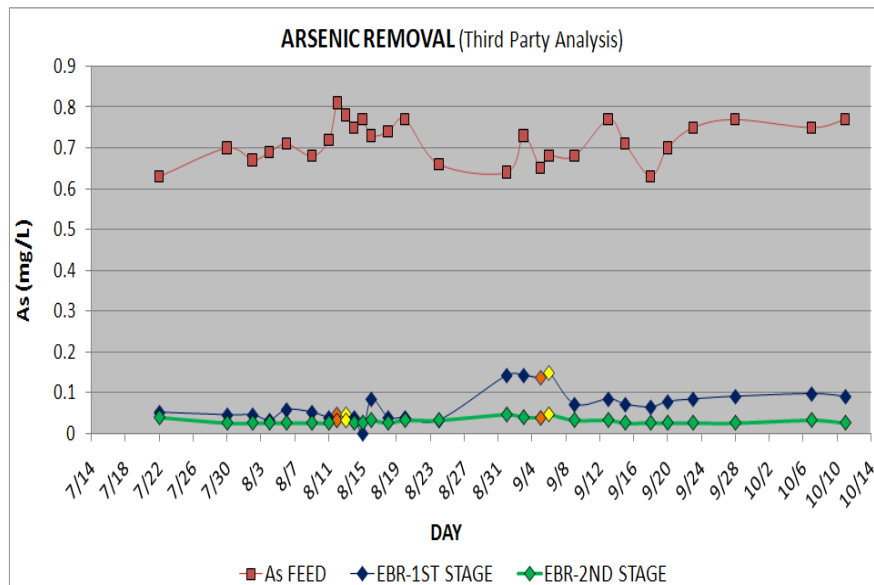
P-1 – Start-up
P-2 – Operation
P-3 – Shut down

*Average system temperature 17 °C
** Temperature range through system 24 ° to 7 °C
*** Average temperature drop through the system 7 °C

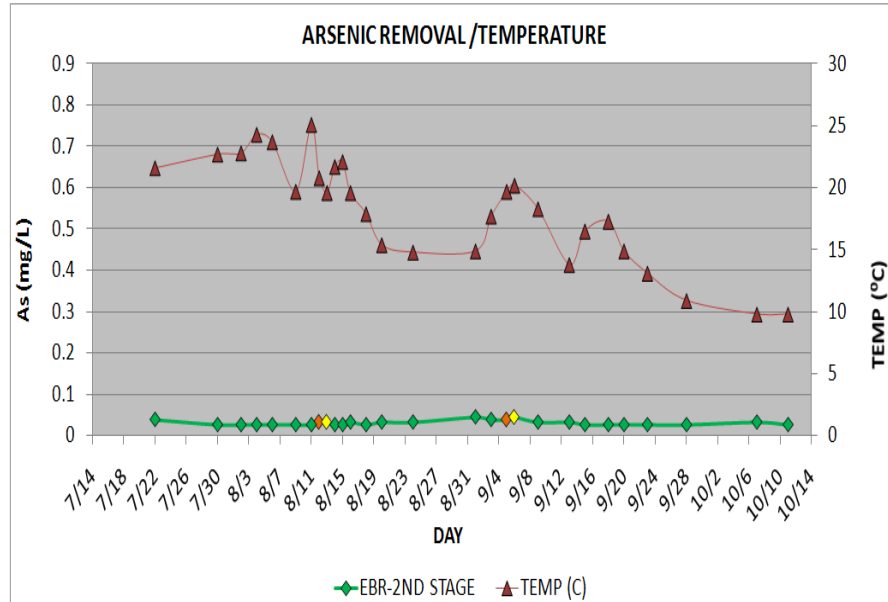
Pilot-scale Validation and Evaluation ***Other Metal Removal***

Metal	Discharge Limit [ppb]	Average Influent [ppb]	Average EBR Effluent [ppb]	Average % Removal
Antimony (Sb)	80	31	3	82%
Arsenic (As)	50	14	6	72%
Cadmium (Cd)	2	1.1	0.2	66%
Lead (Pb)	20	65	1	97%
Molybdenum (Mo)	730	65	3	95%
Selenium (Se)	20	923.2	20.0	99%
Silver (Ag)	1	3	0.2	94%
Zinc (Zn)	500	37	14	45%

Pilot-scale EBR - Arsenic



Pilot-scale EBR - Arsenic



Customers/Costs

Current Customers

WORLD'S LARGEST MINING COMPANIES



Assessments	\$5,000 to \$15,000
Bench Tests	\$30,000 - \$58,000
Pilot Tests	\$85,000 - \$250,000
Full-Scale	\$500,000 - \$6,000,000 ⁺

Summary

EBR process advantages for metal and inorganic removal include:

- Native, non-pathogenic microbes
- 2 to 10 times faster contaminant removal
- $\geq 30\%$ lower capital costs
- $\geq 50\%$ less operational nutrient/reagent costs
- More controllable, stable, and robust reactor environments
- Significantly lower contaminant levels in effluent waters
- Power requirements for a full-scale facility can be supplied by a small solar grid – 1 to 3 volts potential

10 successful bench scale tests for various mines & contaminants

- Selenium and Nitrate
- Arsenic and Nitrate
- Mercury and other contaminants

2 successful on-site, pilot-scale test for arsenic, selenium and nitrate and two more scheduled in 2012

EBR technology starts with the best aspects of proven microbial systems and takes them to the next level of performance and cost-effectiveness.



**CLEAN WATER FOR
A THIRSTY WORLD**

Jack Adams
801-712-2760
jack.adams@utah.edu

